Selection of Medical Laboratory and Clinical Locations in Ghana Using Decision Modeling

by

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ABSTRACT

This field problem was to select the location of up to 400 medical clinics in Ghana. Locations of regional hubs which will serve as distribution centers and labratories for the clinics were also selected. This study utilizes the criteria set by Micro-Clinic and the pilot analysis completed by UW-Stout to select the optimum locations for these clinics, thus maximizing the availability of health care to the people of Ghana.

Micro-Clinic is funding the construction of 400 clinics in Ghana and will franchise them to local health care professionals. These clinics will increase the availability of health care to the rural population of Ghana and help reduce the exodus of health care professionals to other countries by creating opportunities in their home country.

A decision model was built in Microsoft Excel, and this model was used to decide the optimum location for clinics and hubs. The terrain, transportation systems, and population density, and currently available health care were used as criteria for determining the location of the facilities.

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Chapter I: Introduction

Minneapolis, MN based Micro-Clinic is building a network of franchised clinics in Ghana, Africa (Figure 1). The clinics will be supported by regional hubs, which will also serve as distribution centers (Micro-Clinic, 2009). The purpose of this study is to select the location of the clinics and hubs, meeting the criteria set by Micro-Clinic.

Figure 1. Map of Ghana in Africa
(Ghanaweb.com, 2009)

Health care in Ghana faces two major challenges. The first challenge is access to health care. Since most health care is offered in urban areas, citizens in rural communities have difficulty traveling to the urban areas to access the facilities.

The second challenge is the lack of health care professionals. These professionals are leaving the country to seek more lucrative opportunities in other countries.

To address these challenges, Micro-Clinic is developing a network of clinics to be located in rural areas that consist of approximately 10,000 to 20,000 people within walking distance of

the clinic. They will be located in areas not currently serviced by government sponsored facilities and will be franchised to nurses in the local communities to offer an incentive for these professionals to remain in the area. The clinics will offer vaccinations, medications, family planning, preventative care, and routine medical consultations.

The clinics will be supported by regional clinics, which will double as laboratories (hereafter referred to as "hubs"). The hubs will serve as distribution centers for medications and supplies, and will conduct lab testing, training, and support for their assigned clinics. A pilot study of the Volta Region was conducted by the University of Wisconsin – Stout (Lacksonen, 2008). The study determined the placement criteria for these facilities:

1. Clinics should serve up to 20,000 people.
2. Hubs should be located within two hours of clinics.
3. Hubs should serve eight to fourteen clinics.

Statement of the Problem

Where do you locate 400 medical clinics and hubs in Ghana to allow easy access and maximize health care coverage of the rural population?

Purpose of the Study

The purpose of the study is to determine the location of up to 400 medical clinics in Ghana. Locations of regional hubs, which will serve as distribution centers and labratories for the clinics, will also be selected. This study will utilize the criteria set by Micro-Clinic and the pilot analysis completed by UW-Stout, to select the optimum locations for these clinics and hubs.

These clinics will increase the availability of health care to the rural population of Ghana, and help reduce the exodus of health care professionals to more developed countries by creating opportunities in their home country.

Assumptions of the Study

1. Large cities already have well staffed hospitals and clinics.
2. Major roads allow for faster travel.
3. 76% of the population lives in rural areas.
4. All clinics are relatively the same size and capacity and will cost the same to build.
5. Methodology used in the Volta Region pilot study will work in all regions, with the exception of the Northern, Upper West, and Upper East regions.

Limitations of the Study

1. This result of this study provides maximum possible coverage of the rural population and not full coverage.
2. Urban centers where health care is available are not included in the study.
3. Locations that have no serviceable roads or cannot be serviced by a hub are not included in the selection.
4. The Volta Region already covered by the pilot study is not included.
5. Due to the population dispersion in the Northern, Upper East, and Upper West regions, a different model is required and therefore not included.

Methodology

A decision model was built in Microsoft Excel, and this model was used to decide the optimum location for clinics and hubs. The terrain, transportation systems, population density, and currently available health care were used as criteria for determining the locations.

Chapter II: Literature Review

Introduction

This chapter explores the challenges facing the Ghanaian health care system as well as similar improvement programs implemented in other African countries. There is also a discussion of decision modeling, specifically location-allocation models and Solver, which were used to calculate the decisions for this project.

Ghana

One of the main obstacles to improving the health care in Ghana is the emigration of qualified health care workers (Taylor, 2008). There are six doctors for every 100,000 Ghanaians, and approximately 65% of health care professionals leave the country annually to seek opportunities in developed countries. This problem is not limited to Ghana, but is prevalent in all of sub-Saharan Africa (SSA). According to the 2006 World Health Report (World Health Organization, 2006), the number of health care workers needed in Africa must increase by 139% to adequately combat the ever increasing affliction of diseases.

Kirigia (2007) discusses three categories of emigrant workers: those who train overseas and never return, those who return after training overseas and leave after a short period of time, and those who train in SSA and leave once their training is complete. This leaves the SSA countries with a lack of qualified health care professionals, and more importantly, seasoned health care professionals.

The emigration of qualified health care workers also equates to a tremendous economic loss. Awases (2007) states Ghana lost nearly $49 million invested in educating health care professionals due to emigration, and lists several factors for the loss of health care workers. These can be narrowed down to poor working conditions and limited opportunity for growth or advancement.

The second obstacle to improving health care in Ghana is limited access to health care. Taylor (2008) estimates health care is inaccessible to over 70% of the rural population. This equates to approximately twelve million people. Most health care facilities are located in urban areas making it extremely difficult for the rural population to reach these facilities.

Travel to urban areas is achieved mainly by feeder roads. The total length of feeder roads expanded from 23,999 km in 2000 to 40,670 km in 2008, of which 97% are unpaved "earth and gravel" roads. However, due to the focus on the expansion of the feeder roads, maintenance of the existing feeder roads began to deteriorate (Ministry of Transportation, 2008). Figure 2 indicates the condition mix of the unpaved feeder roads in Ghana.

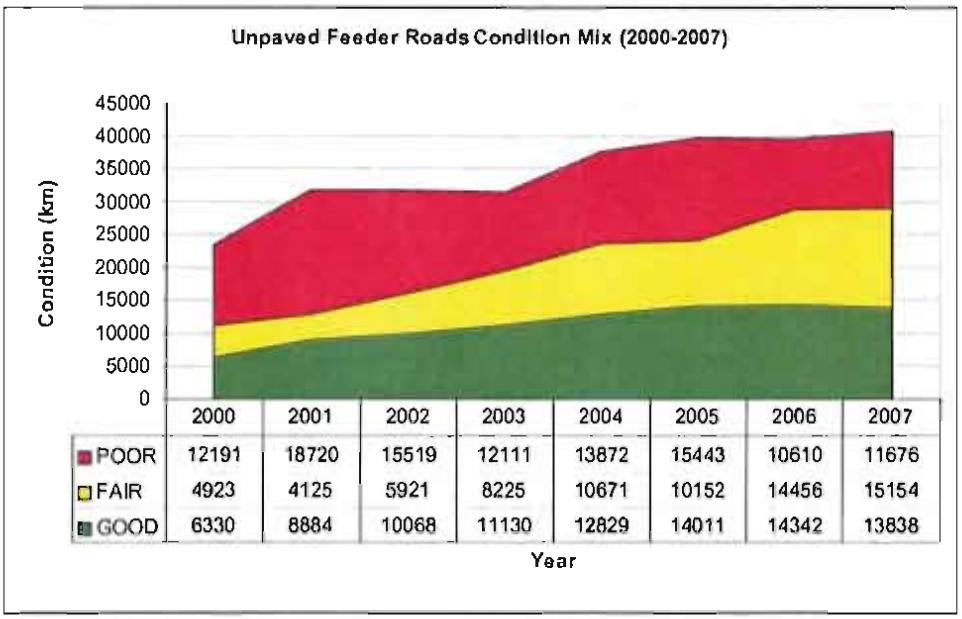

Figure 2. Condition Mix of Unpaved Feeder Roads
(Ministry of Transportation, 2008 p.42)

While the length of these feeder roads continues to expand, a report from the Ministry of Transportation (2008) indicates there is much improvement needed in the expansion and maintenance of the road system to reach the objective of "providing improved access for the movement of people and goods to facilitate the promotion of economic activities and access to social services in rural communities" (p. 46).

Medical Clinic Franchising

The system of building and franchising clinics has been tried and tested in other SSA countries with great success (Seid, 2007). The Healthstore Foundation is running a similar program in Kenya, called *CFW Shops*, where 48 clinics have been franchised. As a result, the clinics are seeing approximately 500,000 patients per year, and the number of diseases being treated is on the decline (Hillstrom, 2008).

Not only is health care more accessible, but the level of service is much higher (Waithaka, 2007). The government clinics are crowded, always lack supplies, often misdiagnose illnesses, and the staff is rude and insulting. The *CFW Shops* clinics are more expensive but worth the additional expense since they are closer, faster, offer a higher degree of service, and are always well stocked.

Not only can franchised clinics offer better service, but they have excellent potential for success (Seid, n.d.). The Department of Commerce estimates over 80% of independent small business fail in the first five years. Compared to an estimate by The International Franchise Association, 5% of franchises fail over the same period (as cited in Seid, n.d.).

By franchising, the clinics will have the buying power and brainpower of a much larger business (Taylor, 2008). A network of clinics, all sharing their experiences and ideas, and learning from each other's mistakes, will support them. The franchisees will also benefit from the training and operational support from Micro-Clinic. This plan will take the health care to the rural people, reducing or eliminating the need to travel to hospitals in urban areas, and increasing the availability and quality of health care in Ghana.

Decision Modeling

Cox (2008) defines decision modeling as "a scientific model (or approach) that helps a decision maker analyze a problem and formulate a solution" (p. 1). The most common form of decision modeling is mathematical programming, where a solution to a problem is

mathematically optimized (maximized or minimized). This can be easily accomplished using a spreadsheet such as Microsoft Excel. Using Excel, the problem is first converted to an abstract (mathematical) representation of the problem, eliminating unnecessary details, and assuming as much as possible (Druzdzel & Flynn, 2002).

Mathematical programs consist of three components: decision variables, constraints, and the objective function (Cox, 2008). Decision variables are the numbers in the problem to be adjusted which affect the outcome. Constraints are restrictions placed upon the program which limit the decision variables. The objective function is the outcome to be optimized.

Once the model is built in a spreadsheet, a tool like Solver can be applied to find the optimum solution. Solver, a graphical user interface (GUI) supplied with Microsoft Excel, is the most popular tool used for optimizing (Fylstra, Lasdon, Watson, & Waren, 1998).

In a very simple example, Peltier Technical Services (2009) demonstrates how Solver can be used to determine the maximum possible product of two factors, if the factors cannot exceed four (See Figure 3). In this example, "Factor 1" & "Factor 2" (B5 & B6) are the decision variables, "Product" (B8) is the objective function, and the constraint is limiting the factors to a maximum value of four.

Once the spreadsheet is programmed to multiply the factors, Solver is opened and programmed. Solver is told to maximize the target cell B8 by changing cells B5 & B6, subject to the constraint, B5 and B6 must each be less than or equal to four. Once programmed, clicking the "Solve" button tells Solver to find a solution.

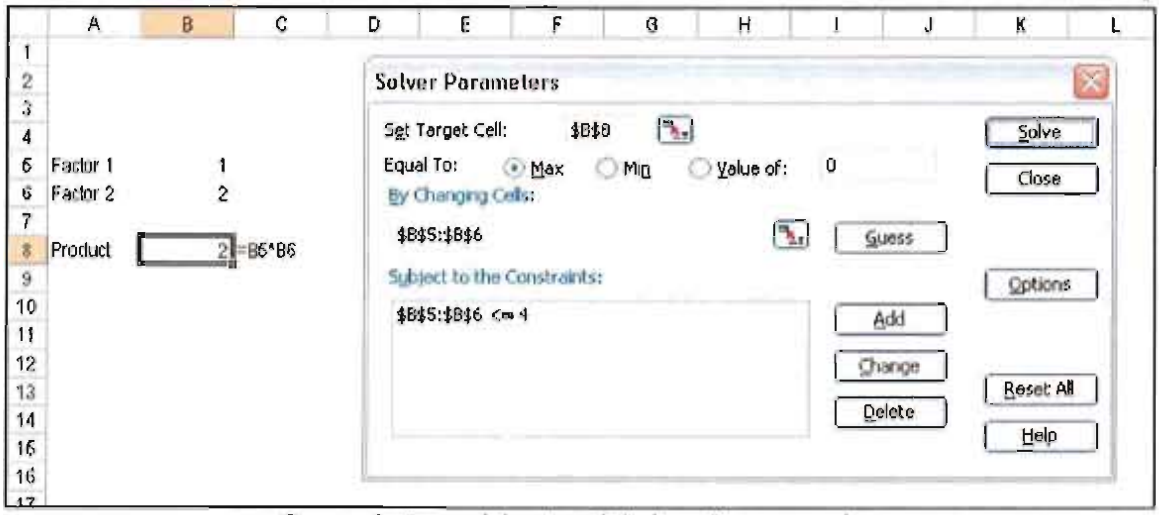

Figure 3. Spreadsheet and Solver Programming
(Peltier Technical Services, Inc., 2009)

Once Solver finds a solution, it makes the changes and asks the user to accept or decline the results. In this case, Solver determined "16" was the maximum possible product by changing both factors to four. Figure 4 shows the final solution and the results accept/decline screen.

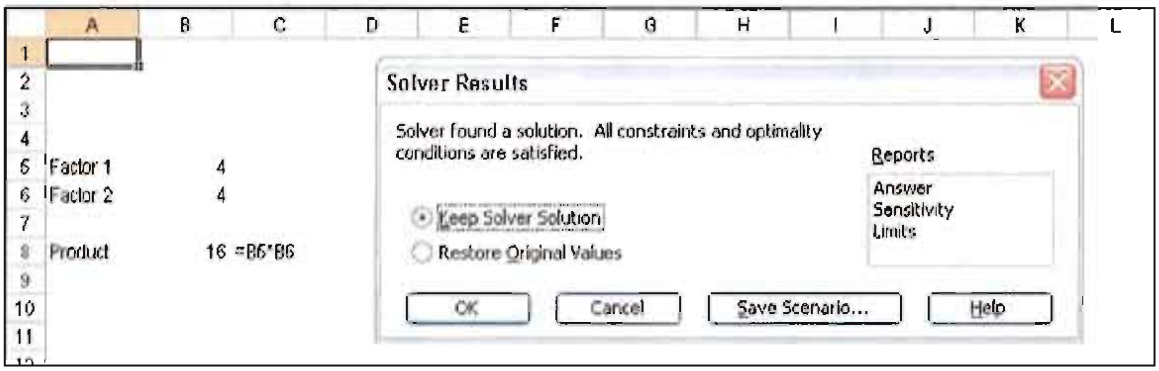

Figure 4. Solution Using Solver
(Peltier Technical Services, Inc., 2009)

The standard Solver program packaged with Excel is limited to 200 decision variables and 100 constraints for linear models (Frontline Systems, 2009). The largest model in this project was the Eastern Region, containing 422 variables and 492 constraints. Since the models in this project exceeded the standard Solver limitations, Premium Solver was needed. Premium Solver can handle linear problems with 2,000 variables and 8,192 constraints (Frontline Systems, 2009).

Location-Allocation Models

There are numerous types of models that can be created and solved using Solver. The model used in this study is a "Location-Allocation" model. These are typically used when

designing distribution networks for retail, warehouses and factories, computer networks, transportation routes, and delivery routes (Current, Daskin & Schilling, 2001). This study specifically used a p-hub center model (Campbell, Lowe, & Zhang, 2005). The p-hub center model designates nodes on a network as hubs, assigns the non-hub nodes to the hubs, and minimizes the maximum travel time between hubs and nodes, while meeting capacity constraints (Campbell et al., 2005).

The p-hub center model can be further broken down into a p-hub center location problem, and a p-hub center allocation problem. The p-hub center location problem selects the nodes, which will serve as hubs. Once completed, the p-hub center allocation problem assigns the nodes to the hubs that will serve them (Campbell et al., 2005).

Due to the complex nature of these types of problems, there is no standard model that applies to every situation and finding an optimum solution can be difficult (Current et al., 2001). Location models must be built for each specific problem, and as a result, most literature on the subject addresses general location model theory or modification of existing models to reach a solution (Current et al., 2001). Until computer technology became fast enough to make the computations necessary, location models were not widely used (Current et al., 2001).

A location-allocation model was built in an Excel spreadsheet for the pilot study. Travel time between potential hubs and clinics was entered. Solver was programmed to select (decision variables) which clinics would serve as hubs (p-hub center location problem) and to assign each clinic to a hub (p-hub center allocation problem). All clinics would need to be serviced and the number of clinics per hub was between eight and fourteen (constraints). Solver was also instructed to minimize the average travel time (objective function). The pilot study selected four hubs to serve 44 clinics in the Volta Region (Lacksonen, 2008).

Chapter III: Methodology

Overview of Problem and Objectives

Micro-Clinic wanted to determine the location of up to 400 medical clinics and regional hubs in Ghana. This study utilized the criteria set by Micro-Clinic and the pilot analysis completed by UW-Stout (Lacksonen, 2008) to select the optimum locations for these clinics.

Clinic and potential hub locations were selected and the travel time between potential hubs and clinics was measered and entered into a mathematical computer model. This model was then used to determine the optimum number and location of hubs, as well as, the clinics assigned to them.

Methods

Analyze population statistics. The pilot analysis recommended serving 10,000 to 20,000 people per clinic. The 2000 census data is the most current, complete population data available (as cited in Lacksonen, 2008). Since the study is to focus on rural areas, the region of Greater Accra, and the cities of Kumasi, and Takoradi/Sekondi were subtracted from the total population.

Using this adjusted population, the number of clinics needed in each region was determined. The regions' percentage of overall adjusted population determined the number of clinic locations to be selected.

Select clinic locations. Using the 2000 census data and a map of Ghana (Surf Publications, 2006), clinic locations were selected in large cities, district capitals, and areas of large population concentration. The number of clinics in each region reflected the number determined in the analysis of the population statistics.

Select potential hub locations. Clinics with the potential to also serve as hubs were identified. These sites were located along main roads and intersections. The sites identified would have the potential to reach eight to fourteen clinics within two hours travel time.

Collect transportation data. Travel time between potential hubs and clinics to be serviced was measured. Using the map of Ghana (Surf Publications, 2006), travel times were measured and calculated assuming an average speed of 55 km/hr on major roads, 35 km/hr on secondary roads, and 25 km/hr on "other roads" (un-maintained dirt roads and two-wheel tracks).

Determine the location of required hubs and assign the clinics to be served. Using the travel times from the transportation data, a decision model was used to select the locations of the hubs and the clinics assigned to each hub. The travel times between clinics and potential hubs were entered into a Microsoft Excel spreadsheet. Premium Solver was used to calculate the average travel time between hubs and clinics using the least amount of hubs to service all clinics, while limiting the number of clinics serviced by each hub to between eight and fourteen.

Micro-Clinic preferred the number of clinics per hub remain between ten and fourteen with the travel time per clinic of approximately 60 minutes. The model was first calculated using ten to fourteen clinics. If no feasible solution could be found, the minimum number was adjusted down toward eight until a solution could be found. The number of hubs was then forced up and down by one or two hubs, noting the average travel time when a feasible solution could be reached. This process was repeated for all regions until an acceptable solution was found for each region.

Chapter IV: Results

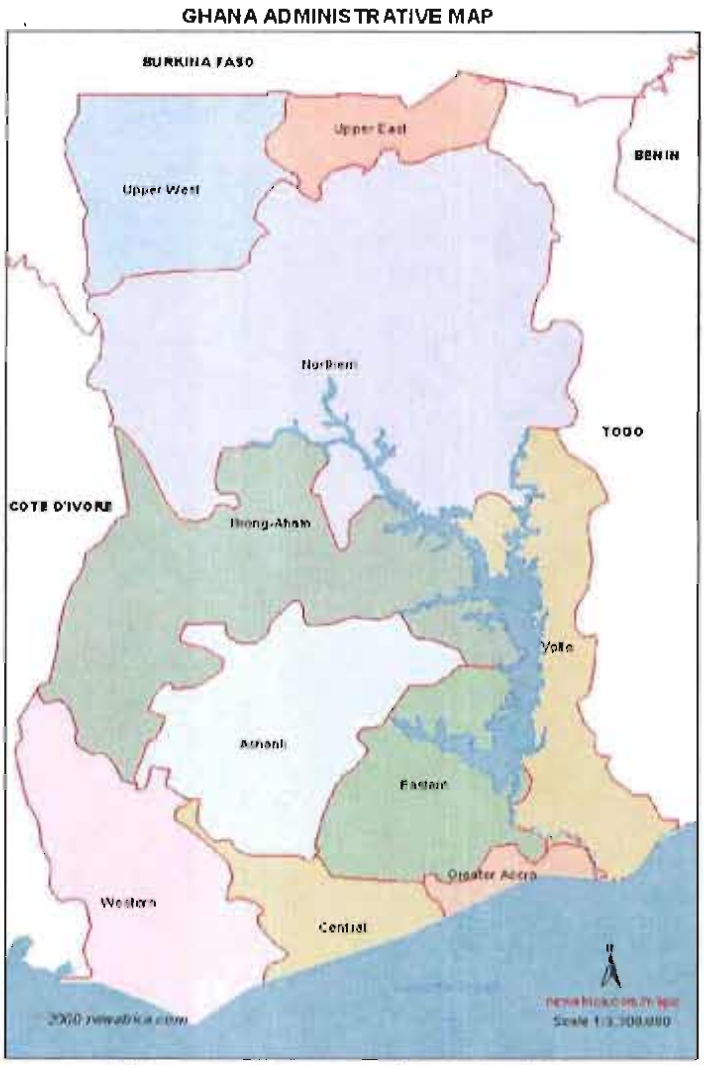

Figure 5. Ghana Administrative Map
(NewAfrica.com, 2000)

Results

Analyze population statistics. The number of clinics in each region (Figure 5) needed to be determined. Since the study was to focus on rural Ghana, large population areas were eliminated from the overall population total. The adjusted population of each region was then divided into the total adjusted population to determine the percentage of the 400 clinics each region would receive. The results of these calculations are shown in Table 1 (the Northern, Upper East, and Upper West regions contain zero actual clinics as they were excluded).

The Greater Accra Region (2.9 million) was eliminated completely due to the population density. The city of Greater Kumasi (1.3 million) was eliminated, reducing the Ashanti region

from 3.2 million to 1.9 million. The "twin cities" of Takoradi and Sekondi (0.3 million) were eliminated, reducing the population of the Western Region from 1.8 million to 1.5 million people. These eliminations adjusted the overall population included in the study from 18.3 million to 13.8 million people.

Table 1.

Population Distribution – Regions of Ghana *Population in millions

Region	Population*	(%)	Adjusted Population*	(%)	Estimated No. Clinics	Actual No. Clinics
Ashanti	3.2	17.5%	1.9	13.8%	55	60
GreaterAccra	2.9	15.8%	-	0.0%	0	0
Eastern	2.1	11.5%	2.1	15.2%	61	59
Northern	1.8	9.8%	1.8	13.0%	52	0
Western	1.8	9.8%	1.5	10.9%	43	52
Brong Ahafo	1.8	9.8%	1.8	13.0%	52	48
Volta	1.6	8.7%	1.6	11.6%	46	44
Central	1.6	8.7%	1.6	11.6%	46	48
Upper East	0.9	4.9%	0.9	6.5%	26	0
Upper West	0.6	3.3%	0.6	4.3%	17	0
Total	18.3	100.0%	13.8	100.0%	400	311

The adjusted population of each region was divided into the total adjusted population to determine the number of clinics each region should receive. As an example, the Ashanti Region should receive 55 clinics as this area equates to 13.8% of the total population (1.9 / 13.8 = 13.8%). 13.8% of 400 total clinics equals 55 clinics in the Ashanti Region. This process was repeated for each of the remaining seven regions.

Select clinic locations. Cities with large population densities in and around the city were selected for clinic locations. These selections were based on 2000 census data and first hand knowledge of three Ghanaian nationals. Cities with large populations were selected to receive a

clinic for every 20,000 people. Each region received the number determined in the analysis of the population statistics (Table 1). The clinic selections can be found in Appendices A-E.

Select potential hub locations. Clinics with the potential to also serve as hubs were identified. These sites were located along main roads and intersections. These sites would have the potential to reach eight to fourteen clinics within two hours travel time. The potential hub selections can also be found in Appendices A-E.

Due to the sparse population distribution and increased travel times in the Northern, Upper East, and Upper West Regions, it was determined these regions would require a different model. A new set of selection criteria would be required for these regions and they were dropped from this study. Table 1 shows the actual number of clinics in each region after adjustments were made for dropped cities and regions.

Collect transportation data. Travel time between potential hubs and clinics to be serviced was measured. Using the map of Ghana (Surf Publications, 2006), travel times were measured and calculated assuming an average speed of 55 km/hr on major roads, 35 km/hr on secondary roads, and 25 km/hr on "other roads" (un-maintained dirt roads and two-wheel tracks). Any city within two hours of the potential hubs was included and the travel time recorded. Cities in excess of two hous travel time from any potential hub were dropped. The transportation data and dropped cities are listed in Appendices A-E.

Determine the location of hubs and assign the clinics to be served. Using the travel times from the transportation data, Premium Solver was used to select the locations of the hubs and the clinics assigned to each hub. The models were designed with the following components:

1. *Objective Function* - Minimize average travel time per clinic. This was calculated by dividing the total travel times between hubs and clinics, by the number of clinics.

2. *Variables*

    a. Yes or No decision as to whether a potential hub was selected to be used as a hub. This was a binary decision using 1 for yes and 0 for no.

    b. The clinics were then assigned to the hubs so that all clinics were served by a hub. This was also a binary decision using 1 for yes and 0 for no.

3. *Constraints*

    a. The first constraint placed on the model was to only allow clinics to be assigned to locations selected to serve as hubs.

    b. A second constraint was then added to only allow sites to be selected with transportation data (within two hours travel time) entered into the model.

    c. A constraint was added to ensure a hub served every clinic.

    d. Constraints were placed on the total clinics per hub to limit the total to between ten and fourteen clinics.

Although the pilot study recommended eight to fourteen clinics, MicroClinic preferred each hub serve ten to fourteen clinics. When a solution could not be reached with at least ten clinics, the model was re-run reducing the minimum to nine and eight. In the Central and Western regions, a solution could not be found with at least ten clinics per hub. Nine was the required minimum in these regions to reach a feasible solution. Table 2 shows the recommended hub selection and number of clinics per hub (in bold), as well as alternative solutions. The specific clinics assigned to each hub are listed in Appendices F-J.

The average time per clinic can be found in Table 3, with the recommended solution highlighted in bold. In regions where multiple solutions were found, the solution with the least number of hubs without exceeding 60 minutes average travel time was recommended. The alternative clinic and hub assignments are listed in detail in Appendices K and L.

Table 2.
Hub Selection and Number of Clinics per Hub

Region	Hubs & No. Clinics/Hub					
Ashanti	Agona Akrofoso	Konongo-Odumase	Mankranso	Manso Nkwanta	Obuasi	
	14	**10**	**10**	**14**	**10**	
Brong Ahafo	Dormaa Ahenkro	Goaso	Sunyani	Techiman		
	10	**14**	**14**	**10**		
Central	Agona Swedru	Breman Asikuma	Cape Coast	Dunkwa-on-ofin	Apam	
	9	**14**	**14**	**11**		
	9	10	11	9	9	
Eastern	Akim Oda	Kibi	Koforidua	Mpraeso	Somanya	
	12	**14**	**10**	**10**	**13**	
Western	Asankragua	Asempanaya	Axim	Daboase	Sefwi Wiawso	Tarkwa
	10	**9**	**13**		**9**	**11**
	11	9	8		10	14
	10	8	8	8	10	8

Table 3.
Average Travel Time per Clinic

Region	Minimum Clinics/Hub	Maximum Clinics/Hub	Total Hubs	Total Clinics	Total Travel Time	Average Time/Clinic
Ashanti	**10**	**14**	**5**	**58**	**2,762**	**48**
Brong Ahafo	**10**	**14**	**4**	**48**	**1,972**	**41**
Central	**9**	**14**	**4**	**48**	**1,858**	**39**
	9	14	5	48	1,808	38
Eastern	**10**	**14**	**5**	**59**	**2,161**	**37**
Western	**9**	**14**	**5**	**52**	**3,000**	**58**
	8	14	5	52	3,571	69
	8	14	6	52	2,844	55

The recommended clinics and hubs were plotted on maps of each region. Figures 6-10 show the location of each clinic indicated by a black dot. The clinics selected to also serve as hubs are indicated by a red dot. Lines demonstrate the clinic to hub assignment.

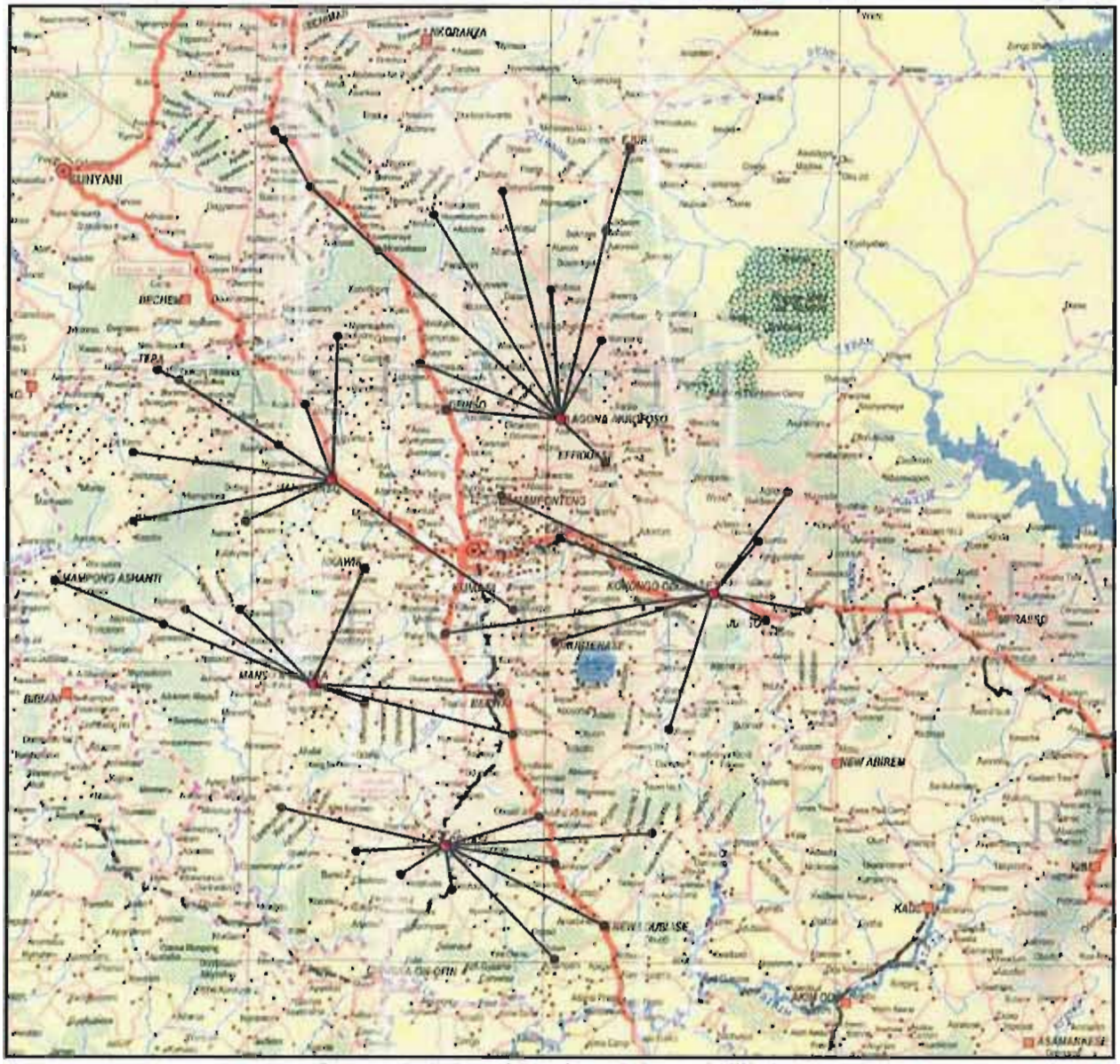

Figure 6. Ashanti Region Hubs and Clinics
(Surf Publications, 2006)

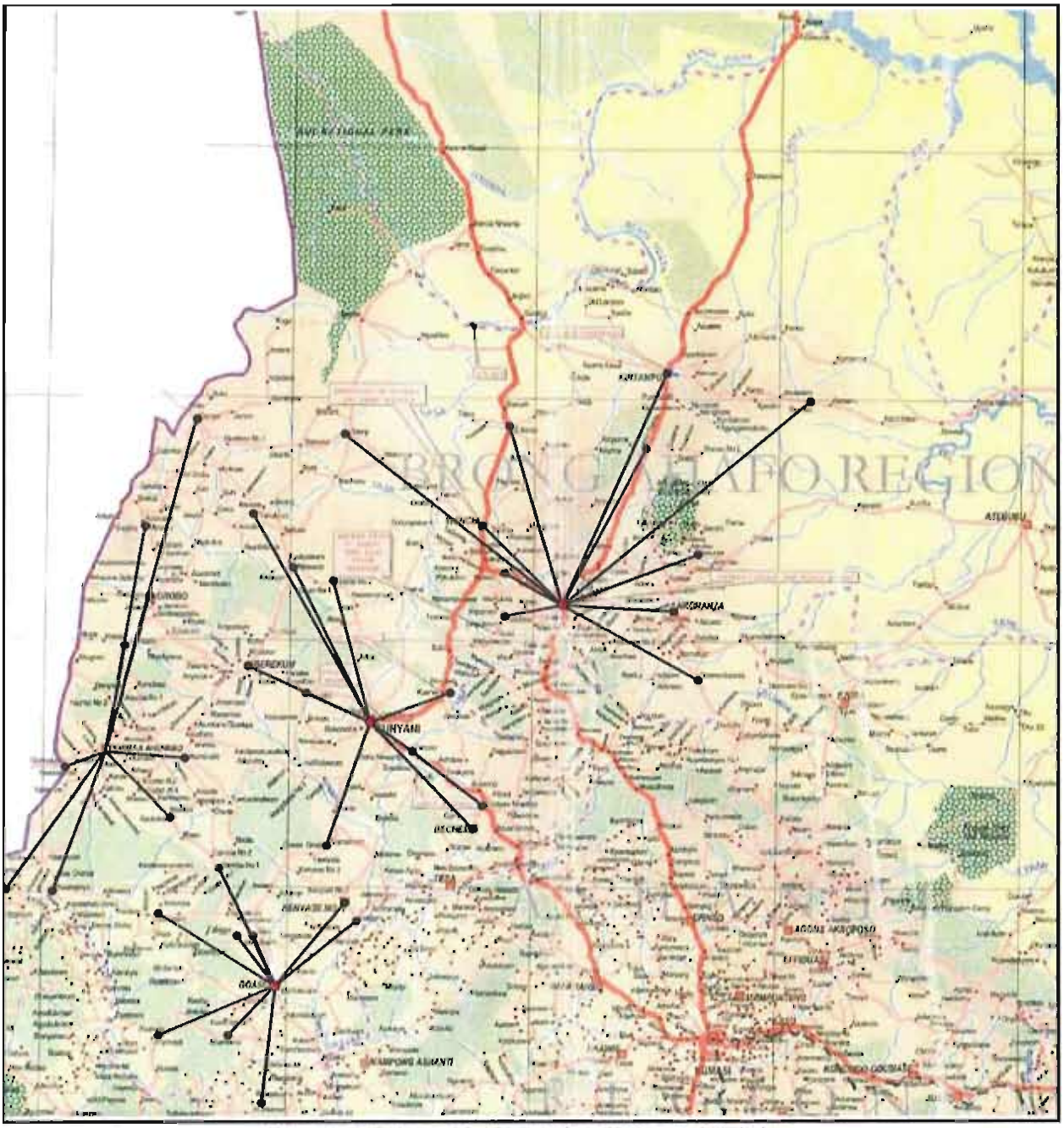

Figure 7. Brong Ahafo Region Hubs and Clinics

(Surf Publications, 2006)

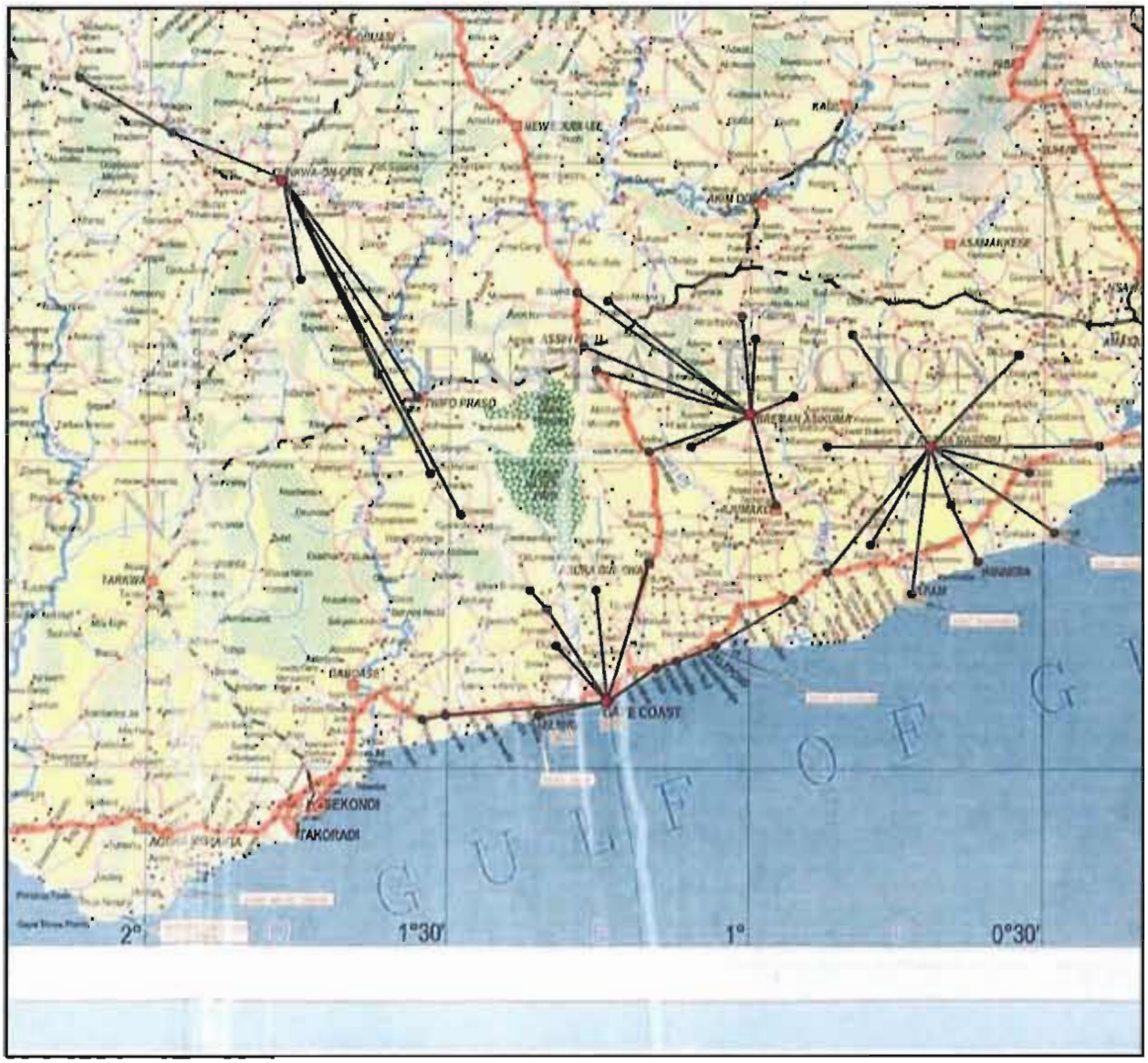

Figure 8. Central Region Hubs and Clinics
(Surf Publications, 2006)

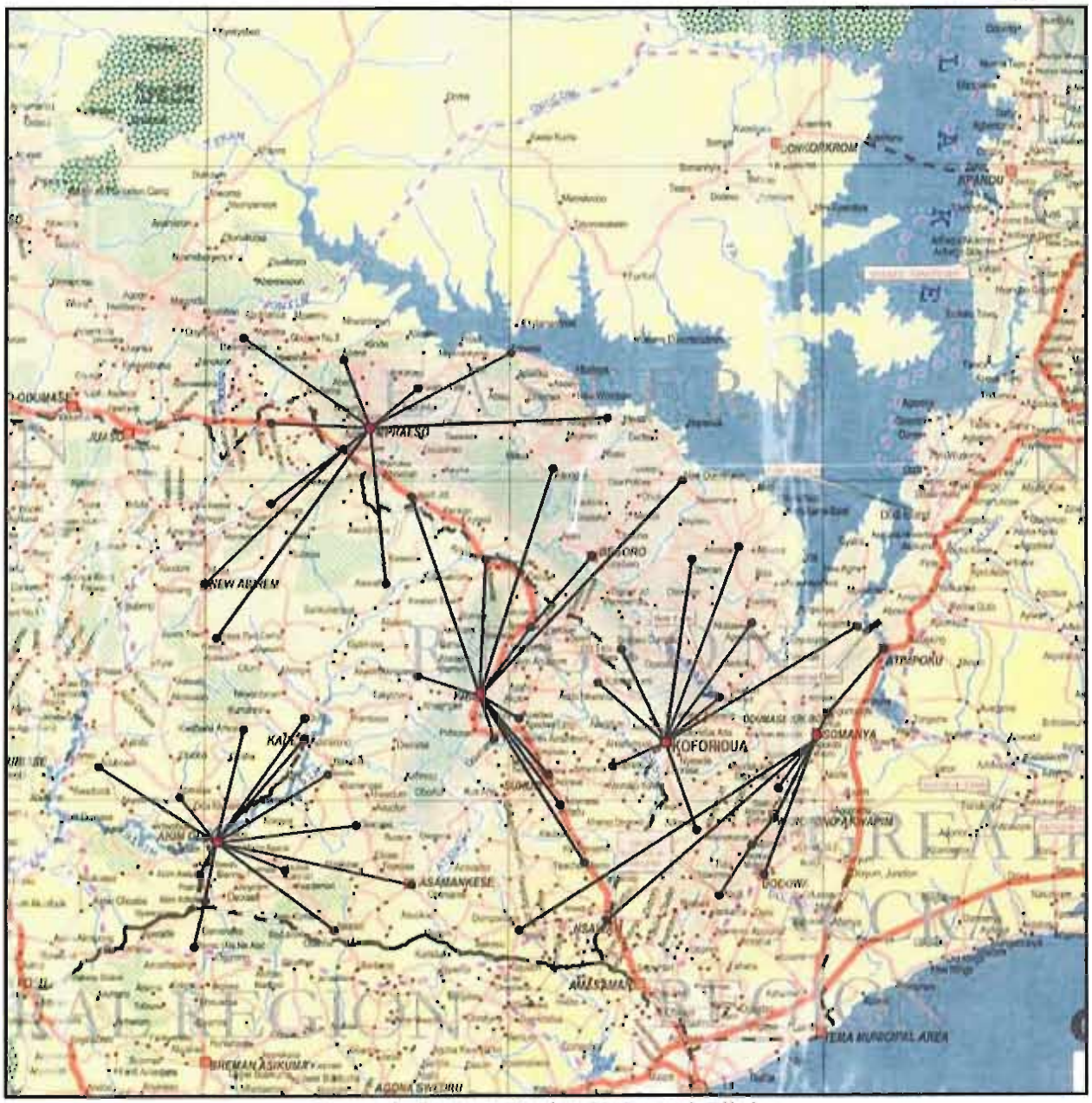

Figure 9. Eastern Region Hubs and Clinics
(Surf Publications, 2006)

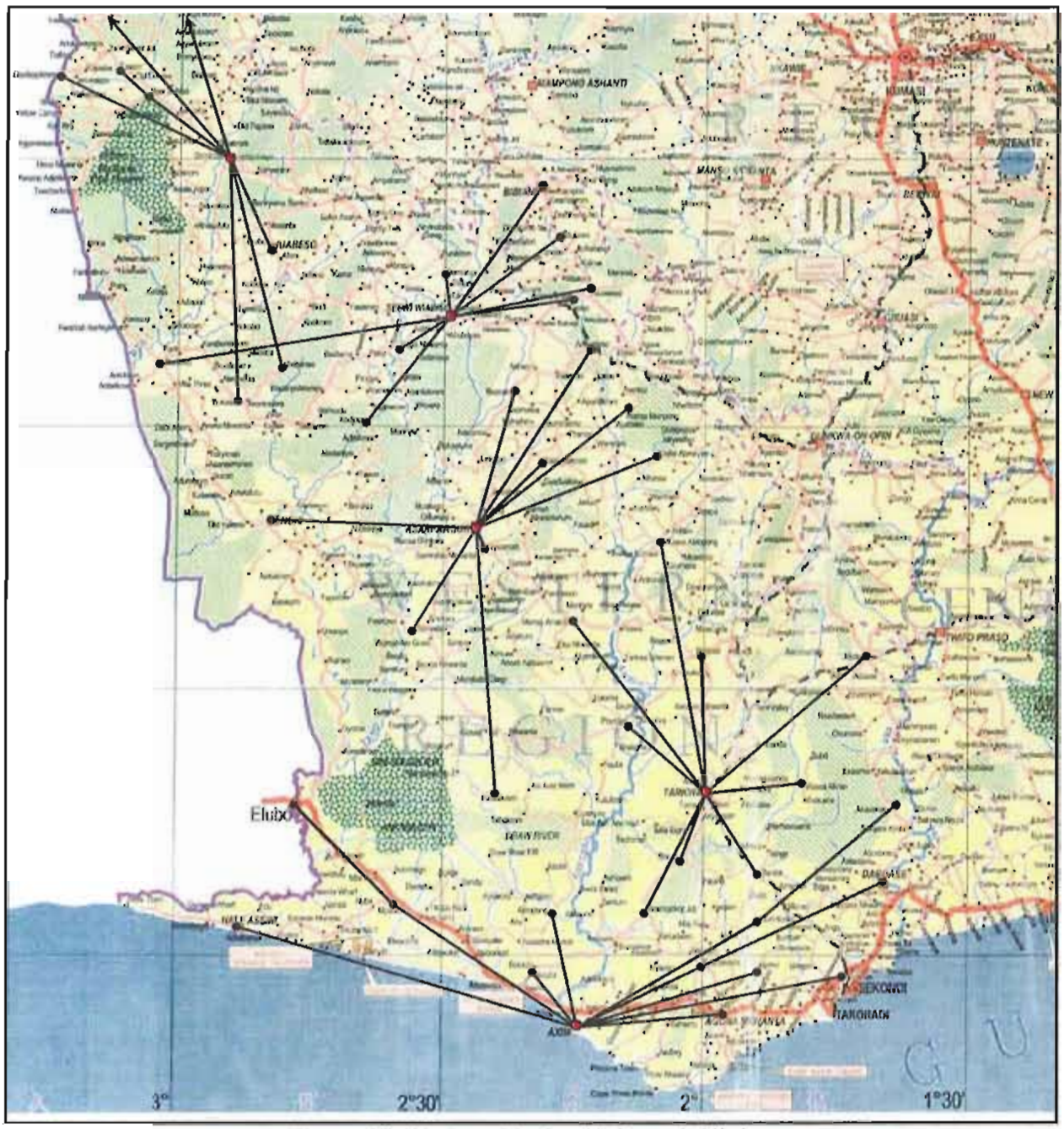

Figure 10. Western Region Hubs and Clinics
(Surf Publications, 2006)

Chapter V: Discussion

Purpose of the Study

The purpose of this study was to determine the location of up to 400 medical clinics in Ghana. Locations of hubs (clinics which will also serve as regional distribution centers and laboratories for the clinics) were also selected. This study utilized the criteria set by Micro-Clinic and the pilot analysis completed by UW-Stout, to select the optimum locations for these clinics and hubs. These clinics will increase the availability of health care to the rural population of Ghana, and help to reduce the exodus of health care professionals to more developed countries by creating opportunities in their home country.

Conclusions

Using the criteria set by Micro-Clinic and the UW-Stout pilot study, the model was built in Microsoft Excel, and Premium Solver found a feasible solution for each region. Table 4 lists the recommended number of clinics and hubs per region, as well as, the average travel time. Specific hub selections and the clinics assigned to them are shown in Appendices F-J. They can also be viewed in Figures 6-10.

Table 4.
Hubs and Clinics by Region

Region	Total Hubs	Total Clinics	Average Time/Clinic
Ashanti	5	58	48
Brong Ahafo	4	48	41
Central	4	48	39
Eastern	5	59	37
Western	5	52	58
Total	23	265	45

Recommendations

Inconsistent maps. During the course of this project, it was discovered there are inconsistencies between available maps of Ghana. The travel time in this project used the "Ghana Road Map" second edition, produced by Surf Publications (2006). These differences include regional borders, spelling of city names, and city locations. The Surf Publications map should be used when referring to this project. For consistency, subsequent projects should refer to the Surf Publications map as well.

Linear decision model. For any subsequent projects, every attempt should be made to create a linear (the product of a constant and a variable) decision model. The initial model for this project was non-linear. This dramatically increased the calculation time for Solver.

The minimum calculation time was twenty minutes, and Solver had to be halted with no optimum decision reached. Once the model was re-created and made linear, the calculation time was reduced to a several seconds, with Solver finding an optimum solution.

Northern, Upper East, and Upper West Regions. The Northern, Upper East, and Upper West Regions should be examined. Due to the concentration of population in a small number of cities, as well as the travel time between these cities, these regions do not fit the model recommended in the pilot study. A new set of criteria should be written for these regions.

One large model. An alternative to building five models (one model for each region) would be to build one large model containing all five regions. Doing so would allow hubs to serve clinics across regional borders. This would allow a realignment of hub and clinic assignments, which may reduce the average travel time and distribute the hub and clinic assignments more evenly.

An example where this would apply would be the North-West Ashanti Region. The clinics in Afrancho and Akumadan are 104 and 100 minutes away from their assigned hub,

Agona Akrofoso. I one large model, these clinics may be reassigned to Techiman in the Brong Ahafo Region. This would reduce the travel time to 22 and 26 minutes respectively.

The drawback to utilizing this format would be the size of the model. The current models contain a total of 1,676 variables. Creating one large model would add more transportation data (clinics within two hours of potential hubs), thus creating more variables.

Since Premium Solver is only able to handle up to 2,000 variables, an investment in Premium Solver Platform may be necessary. Premium Solver Platform is expandable to a virtually unlimited number of variables and constraints (Frontline Systems, 2009). However, the expense of Premium Solver Platform may be offset by more efficient hub and clinic locations.

Reviewing results. Decision models are intended to be a tool to help people make better decisions. Results may be manually overridden to create a solution that may not be optimal, but better fits the scenario, while remaining within specified criteria. As an example, manually reassigning clincs to reduce the number of hubs would increase average travel time, but the increased time my still be an acceptable trade-off to reducing the number of hubs. When using decision models, the results should be carefully reviewed for accuracy and alignment with intended results.

Preliminary clinic and hub site selection. The results of this study are intended to be preliminary recommendations. These selections were made based on first hand knowledge of Ghanaian nationals, 2000 census data, and a Surf Publications map of Ghana. They follow the recommendations of the pilot study performed by UW-Stout, and meet the specifications and requests of Micro-Clinic. It may be determined that more clinics are needed in some areas due to poverty, and less in others due to existing, adequate health care. Micro-Clinic may manually alter the results to better fit the needs of the people of Ghana.

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Appendix A: Ashanti Region Clinics, Potential Hubs, and Travel Time

Hubs / Clinics	Agona Akrofoso	Ofinso	Mankranso	Manso Nkwanta	Obuasi	Konongo-Odumase	New Edubiase	Ejura	Juaso
Tweapease				114	17		71		
Obuasi 5*		109	112	97	1		54		
Obuasi 4*		109	112	97	1		54		
Obuasi 3*		109	112	97	1		54		
Obuasi 2*		109	112	97	1		54		
Obuasi 1*		109	112	97	1		54		
New Edubiase		117	114	99	54		1		
Mampong Ashanti				126					
Barimaena		105	48	118					
Amokrom		106	43	119					
Saponso				112	67	114	54		103
M. Akropong	54	106	87	17	74	104	88		109
Kuntenase	66	64	67	68	67	63	75		74
Nkawie	72	55	36	34	110	78	118		89
Bekwai	78	61	64	49	48	84	56		89
Manso Nkwanta	106	89	70	1	97	112	105		
Akrofuom				109	12		66		
Adansi Asokwa	110	93	96	81	36	116	38		
Anyeme					41		95		
Ayokwa		94	103	82	43	117	23		
Esienkyiem					46		100		
Bogyawe	101	84	87	72	71	107	79		112
Pakyi No.2	71	64	57		75	77	83		82
Aniampam					78		24		
Aputuogya	49	47	50	85	84	80	110		81
Abosoma	121	104	107	92	91	110	99		
Ejisu	39	44	47		99	33	107		44
Ofinso	42	1	57	89	109	77			78
Mankranso	74	57	1	70	112	80	120		91
Effiduase	17	59	69		121	55		108	66
Adumasa	106	89	70	51		112			
Agona Akrofoso	1	42	74	106		72		91	83
Anyinasuso	51	9	66	98		86			87
Nkwaakwaa	75	33	90	122		110		122	111
Odikuro Nkwanta	106	98	41	111					
Akorabuorkrom	115			104					
Asuadei	91	74	17	87		97			108
Baaniekrom	91	74	17	87		97			108
Mamponteng	29	42	45	77		65	105	117	76
Nyinahin	79	106	87	68					
Kofiase	49	95	117			121		82	
Mampong	29	75	97			101		62	112
Ofoasa	126					54			43
Agogo	77	119				37			48
Asankare	92	97	99			20			9
Juansa	95	96	110			19			30
Juaso	83	88	91			11			1
Konongo-Odumase	72	77	80			1			11
Tera	118	110	53						
DC Krom			75						
Manhyia			81						
Kwackesiem	93	51	104						
Akumadan	100	58	111						
Afrancho	104	62	115						
Ejura	91							1	
Nyamebekyere No.1	113	71						84	
Sataso	65	111						26	
Sekyedumase	113							48	

* City includes multiple clinics due to large population.

Dropped Kofur Camp

Appendix B: Brong Ahafo Region Clinics, Potential Hubs, and Travel Time

Hubs / Clinics	Kenyase No.1	Dormaa Ahenkro	Drobo	Sunyani	Wenchi	Techiman	Goaso	Berekum	Kintampo
Dormaa Ahenkro		1	57	114			113	69	
Gornokrom		14	71					83	
Wamanafo		26	83	88			105	43	
Abinkasu		43	14	99				54	
Asukokoo	112	43	100	123			70	78	
Kwakuanya		53	110				113		
Drobo		57	1	85				40	
Gambia No.1	86	69		109			44	104	
Yaw Owusukrom		73							
Mpuasu		83	26	111				66	
Mim	60	95		83			18		
Berekum 1*		97	40	45	99	112		1	
Berekum 2*		97	40	45	99	112		1	
Fodwookrom	68	103		91			26		
Sampa		105	69		117			109	
Yerusalem	95	108		118			53		
Goaso	42	113		101			1		
Nsuatre	116	116	59	26	80	93		19	
Ahamtamo	71						29		
Asubura	102						60		
Atrensu				51	15	11		96	67
Bechem			125	40	94	107		85	
Beposo						106			50
Busunya				120	79	53			85
Donkronkwanta					83	57			89
Duayaw Nkwanta	118		113	28	82	95		73	
Hwidiem	8			98			34		
Jema				106	65	39			17
Kenyase No.1	1			90			42		
Kintampo				123	82	56			1
Koofoso				47	47	20		92	76
Kramokrom	43			47	101	114	85		
Menji			126	114	60	86		109	
Nkoranza				103	62	36			68
Nkwanta			77	82	98			37	
Kokote No.2			97	102	118			57	
Resekrom	103						61		
Subinso				76	22	48		121	104
Sunyani 1*	90		85	1	54	67		45	
Sunyani 2*	90		85	1	54	67		45	
Sunyani 3*	90		85	1	54	67		45	
Tanoso	101		96	11	65	78		56	
Tano	108		103	18	36	49		63	105
Tanokrom			113	118	110			63	
Techiman 1*				67	26	1		107	56
Techiman 2*				67	26	1		107	56
Techiman 3*				67	26	1		107	56
Wenchi				54	1	26		99	82

* City includes multiple clinics due to large population.
Dropped Yeji, Pran, Atebubu, and Kwamedanso

Appendix C: Central Region Clinics, Potential Hubs, and Travel Time

Hubs Clinics	Dunkwa- on-ofin	Twifo Praso	Assin Fosu	Abura Dunkwa	Ajumako	Agona Swedru	Cape Coast	Apam	Breman Asikuma
Dunkwa-on-ofin	1	86							
Domenase	34	120							
Kramokrem	36	52	100						
Aboabo	68	18	68	115			120		
Nkwantanum	68								
Agona	85	34	85						
Twifo Praso	86	1	51	98			103		108
Twifo Heman	105	18	70	117			84		
Wawase	120	34	86	92			69		
Aboransa			103	55	93		32	113	
Abura Dunkwa		98	43	1	81	113	26	95	53
Achiase		91		63	101		40	121	
Adubiase		57	6	37	75		60		53
Agona Swedru 1*				113	53	1	111	39	75
Agona Swedru 2*				113	53	1	111	39	75
Ajumako			78	81	1	53	70	85	22
Amanfopong			87	85	50	103	115		28
Anomabu		114	75	28	44	85	17	64	75
Anyinaso		97	40	28	47	100	62		25
Apam				83	76	48	81	1	107
Assin Akropong		86		77	101		86		79
Assin Fosu		51	1	43	78		66		59
Assin Manso		80	23	17	58	111	43	112	36
Biriwa		108	69	23	49	90	12	69	80
Bodjiase					89	36		75	111
Brakwa			78	76	41	94	106		19
Breman Asikuma		115	58	53	22	75	87	107	1
Brofoyedru		62	11	54	92		77		70
Cape Coast 1*		97	69	23	61	102	1	81	92
Cape Coast 2*		97	69	23	61	102	1	81	92
Efutu		78	87	42	80	121	19	100	111
Ekumfi Dunkwa			103	53	46	60	51	30	77
Elmina		108	80	34	72	113	11	92	103
Gomoa			112	61	54	52	59	22	85
Jerusalem					87	34		73	109
Jukwa		69	121	51	89		28	109	120
Kasoa					118	65		70	
Komenda		126	97	51	89		28	109	
Kuntananse			65	68	33	86	98	118	11
Lukwa Breman		60	112	60	98		37	118	
Saltpond		120	83	35	37	78	24	57	68
Mfantseman			101	62	19	34	89	73	41
Nkoranza				74	67	39	80	17	106
Nyakuadze				96	89	17	94	22	92
Ojobi				124	107	54		59	
Senya						74		59	
Winneba 1*				96	89	35	94	22	109
Winneba 2*				96	89	35	94	22	109

* City includes multiple clinics due to large population.

Appendix D: Eastern Region Clinics, Potential Hubs, and Travel Time

Hubs / Clinics	Mpraeso	New Abirem	Akim Oda	Asamankese	Koforidua	Begoro	Kade	Somanya	Kibi
New Abirem	64	1	105	104			49		111
Kwea	81	17	74	87			32		94
Akoase	32	32		0		97	81		90
Subi	113	49	42	55			7		62
Nkawkaw		55		0		74	104		67
Kade	120	56	35	48			1		69
Mpraeso	1	64		0	104	83	113		76
Akwatia		67	46	37		82	11		103
Lejeti Jct.	23	69		0	117	60	118		53
New Fodowa	24	70		0		89	119		82
Kwahu Tafo	15	79				113			91
Kwabena Amoa		82	61	74			26		95
Osenase		84	63	20			28		97
Anyinem	40	86		120	100	43	124		36
Abenase		88	17	93			63		121
Asonafo	50	96	116			87			80
Asamankese		104	76	1	90		48		84
Adowoso North	41	105				87			117
Bunso Jct.	59	105	121	101	81	24	86		17
Akim Oda		105	1	76			35		104
Abene	18	112				101			94
Akim Awisa		114	9	85			44		113
Akim Achiase		123	18	84			53		122
Asuboa		124	19	57			54		123
Dwerebease	52								
Kibi	76		104	84	64	41	69		1
New Tafo	77			119	27	42	104		61
Kwahu Amanfrom	78				117	50			101
Kukorantumi	82			100	22	47	109		56
Begoro	83				105	1	110	120	41
Akyem Akropong	87		80	93	88	65	45		24
Odumase	88		116	72	52	53	81	115	12
Apedwa	96		124	72		61	89	119	20
Asuogra	102					45			90
Koforidua	104			90	1	105		60	64
Suhum	105			55	35	70	98	98	29
New Dorminase	109				86	35		96	76
Amanase	111			61	41	76	104	92	35
Supreso	119			75	15	90	118	75	49
Huhunya	121			107	17	104			81
Teacher Mante	122			76	52	87	124	81	46
Bunso			29	95			64		
Asuoso			39	37			74		121
Adeiso			113	37	91	126	85	98	85
Adubase			42	118			88		
Nsawam				65	63	98	113	70	57
Aburi				97	59			38	89
Adowoso South				113	23			44	87
Adukrom					43			17	107
Akatawia					39			49	
Akosombo					87				
Akropong Akawapim				121	49			21	113
Amanokurom				114	42			25	106
Asesewa					60	61		70	102
Atimpoku					81			21	
Dodowa				119	81			60	111
Donkorkrom									
Dzaman					82	83		92	124
Odumase Krobo					64	116		4	
Somanya					60	120		1	

Dropped Takorowatwen, Tease, and Donkokrom

Appendix E: Western Region Clinics, Potential Hubs, and Travel Time

Clinics \ Hubs	Asempanaya	Juabeso	Sefwi Wiawso	Bibiani	Ankwawso	Beposo	Asankragua	Tarkwa	Axim	Daboase
Adabokrom	91									
Ahebenso	103	43	102							
Asempanaya	1	60								
Blacksmith	92									
Bokaso	120	60	85							
New Debiso	34	94								
Essam	43	103								
Juabeso	60	1								
Oseikojokrom	69									
Bopa Nkwanta		70	19	101						
Dadieso		69	119							
Domeabra		85	11	95						
Kodjour		84	67							
Sefwi Wiawso		94	1	80						
Adukrom			63	17	51	71	128			
Ankwawso			53	64	1	34	85			
Asawinso			45	20	28	51	111			
Asempanaye			36	29	36	43	102			
Beposo			87	94	34	1	60			
Bibiani			80	1	64	94				
Wasa Mampong			86	121	57	91	121			
Enchi			127			128	68			
Kwagyeikrom			113		60	48	36			
Gyaaman					93	68	9	119		
Krobo Abrokyire					72	96	60			
Manso Amenfi					125	102	36	85		
Wasa Akropong					112	110	92	94		
Bogoso							80	43		
Prestea							121	77		
Samreboi					119	94	36			
Kwasikrom							103			
Asankragua					85	60	1		103	
Tarkwa 1*							128	1	103	
Tarkwa 2*							128	1	103	
Daboase									92	1
Kojokrom								119	66	23
Akasakasa									120	26
Agona Nkwata								90	33	51
Mpohor								111	54	65
Kyekyewere								73	50	68
Atieku								120		85
Edumbanso								83	78	89
Axim								103	1	92
Bramienkor Jct.								42	65	100
Nkroful								83	22	112
Benso								59	120	113
Bonsa								23	84	119
Akropong								119	56	
Wasa Nkran								48		
Elubo									67	
Half Assini									96	
Mpatapa									39	

* City includes multiple clinics due to large population.

Appendix F: Ashanti Region Clinic/Hub Assignments

Agona Akrofoso	**Konongo-Odumase**	**Mankranso**	**Manso Nkwanta**	**Obuasi**
Afrancho	Agogo	Amokrom	Abosoma	Adansi Asokwa
Agona Akrofoso	Asankare	Aputuogya	Adumasa	Akrofuom
Akumadan	Ejisu	Asuadei	Akorabuorkrom	Aniampam
Anyinasuso	Juansa	Baaniekrom	Bekwai	Anyeme
Effiduase	Juaso	Barimaena	Bogyawe	Ayokwa
Ejura	Konongo-Odumase	DC Krom	M. Akropong	Esienkyiem
Kofiase	Kuntenase	Manhyia	Mampong Ashanti	New Edubiase
Kwaekesiem	Mamponteng	Mankranso	Manso Nkwanta	Obuasi 1*
Mampong	Ofoasa	Odikuro Nkwanta	Nkawie	Obuasi 2*
Nkwaakwaa	Pakyi No.2	Tera	Nyinahin	Obuasi 3*
Nyamebekyere No.1				Obuasi 4*
Ofinso				Obuasi 5*
Sataso				Saponso
Sekyedumase				Tweapease

* City includes multiple clinics due to large population.

Appendix G: Brong Ahafo Region Clinic/Hub Assignments

Dormaa Ahenkro	**Goaso**	**Sunyani**	**Techiman**
Abinkasu	Ahamtamo	Bechem	Atrensu
Asukokoo	Asubura	Berekum 1*	Beposo
Dormaa Ahenkro	Fodwookrom	Berekum 2*	Busunya
Drobo	Gambia No.1	Duayaw Nkwanta	Donkronkwanta
Gornokrom	Goaso	Kokote No.2	Jema
Kwakuanya	Hwidiem	Kramokrom	Kintampo
Mpuasu	Kenyase No.1	Nkwanta	Koofoso
Sampa	Mim	Nsuatre	Menji
Wamanafo	Resekrom	Sunyani 1*	Nkoranza
Yaw Owusukrom	Yerusalem	Sunyani 2*	Subinso
		Sunyani 3*	Techiman 1*
		Tano	Techiman 2*
		Tanokrom	Techiman 3*
		Tanoso	Wenchi

* City includes multiple clinics due to large population.

Appendix H: Central Region Clinic/Hub Assignments

Agona Swedru	Breman Asikuma	Cape Coast	Dunkwa-on-ofin
Agona Swedru 1*	Adubiase	Aboransa	Aboabo
Agona Swedru 2*	Ajumako	Abura Dunkwa	Agona
Apam	Amanfopong	Achiase	Domenase
Bodjiase	Anyinaso	Anomabu	Dunkwa-on-ofin
Gomoa	Assin Akropong	Biriwa	Kramokrem
Jerusalem	Assin Fosu	Cape Coast 1*	Nkwantanum
Kasoa	Assin Manso	Cape Coast 2*	Twifo Heman
Mfantseman	Brakwa	Efutu	Twifo Praso
Nkoranza	Breman Asikuma	Ekumfi Dunkwa	Wawase
Nyakuadze	Brofoyedru	Elmina	
Ojobi	Kuntananse	Jukwa	
Senya		Komenda	
Winneba 1*		Lukwa Breman	
Winneba 2*		Saltpond	

* City includes multiple clinics due to large population.

Appendix I: Eastern Region Clinic/Hub Assignments

Akim Oda	**Kibi**	**Koforidua**	**Mpraeso**	**Somanya**
Abenase	Akyem Akropong	Adowoso (South)	Abene	Aburi
Adubiase	Amanase	Akatawia	Adowoso (North)	Adeiso
Akim Achiase	Anyinem	Akosombo	Akoase	Adukrom
Akim Awisa	Apedwa	Asesewa	Asonafo	Akropong Akawapim
Akim Oda	Asuogra	Dzaman	Dwerebease	Amanokurom
Akwatia	Begoro	Huhunya	Kwahu Amanfrom	Atimpoku
Asamankese	Bunso Jct.	Koforidua	Kwahu Tafo	Dodowa
Asuboa	Kibi	Kukorantumi	Kwea	Nsawam
Asuoso	New Dorminase	New Tafo	Nkawkaw	Odumase Krobo
Bunso	Lejeti Jct.	Supreso	Mpraeso	Somanya
Kade	Odumase		New Abirem	
Kwabena Amoa	Suhum		New Fodowa	
Osenase	Teacher Mante			
Subi				

Appendix J: Western Region Clinic/Hub Assignments

Asankragua	**Asempanaya**	**Axim**	**Sefwi Wiawso**	**Tarkwa**
Ankwawso	Adabokrom	Agona Nkwata	Adukrom	Atieku
Asankragua	Ahebenso	Akasakasa	Asawinso	Benso
Beposo	Asempanaya	Akropong	Asempanaye	Bogoso
Enchi	Blacksmith	Axim	Bibiani	Bonsa
Gyaaman	Bokaso	Daboase	Bopa Nkwanta	Bramienkor Jct.
Krobo Abrokyire	Essam	Edumbanso	Dadieso	Manso Amenfi
Kwagyeikrom	Juabeso	Elubo	Domeabra	Prestea
Kwasikrom	New Debiso	Half Assini	Kodjour	Tarkwa 1*
Samreboi	Oseikojokrom	Kojokrom	Sefwi Wiawso	Tarkwa 2*
Wasa Mampong		Kyekyewere		Wasa Akropong
		Mpatapa		Wasa Nkran
		Mpohor		
		Nkroful		

* City includes multiple clinics due to large population.

Appendix K: Central Region Alternate Clinic/Hub Assignments

5 Hubs, 9-14 Clinics per Hub

Agona Swedru	Apam	Breman Asikuma	Cape Coast	Dunkwa-on-ofin
Agona Swedru 1*	Anomabu	Adubiase	Aboransa	Aboabo
Agona Swedru 2*	Apam	Amanfopong	Abura Dunkwa	Agona
Ajumako	Ekumfi Dunkwa	Anyinaso	Achiase	Domenase
Bodjiase	Gomoa	Assin Akropong	Biriwa	Dunkwa-on-ofin
Jerusalem	Nkoranza	Assin Fosu	Cape Coast 1*	Kramokrem
Kasoa	Saltpond	Assin Manso	Cape Coast 2*	Nkwantanum
Mfantseman	Senya	Brakwa	Efutu	Twifo Heman
Nyakuadze	Winneba 1*	Breman Asikuma	Elmina	Twifo Praso
Ojobi	Winneba 2*	Brofoyedru	Jukwa	Wawase
		Kuntananse	Komenda	
			Lukwa Breman	

* City includes multiple clinics due to large population.

Appendix L: Western Region Alternate Clinic/Hub Assignments

5 Hubs, 8-14 Clinics per Hub

Asankragua	Asempanaya	Axim	Sefwi Wiawso	Tarkwa
Adukrom	Adabokrom	Akasakasa	Bibiani	Agona Nkwata
Ankwawso	Ahebenso	Akropong	Bokaso	Mpohor
Asawinso	Asempanaya	Asankragua	Bopa Nkwanta	Kyekyewere
Asempanaye	Blacksmith	Daboase	Dadieso	Atieku
Beposo	Essam	Elubo	Domeabra	Edumbanso
Gyaaman	Juabeso	Half Assini	Enchi	Axim
Krobo Abrokyire	New Debiso	Kojokrom	Kodjour	Bramienkor Jct.
Kwasikrom	Oseikojokrom	Mpatapa	Kwagyeikrom	Nkroful
Manso Amenfi		Wasa Nkran	Sefwi Wiawso	Benso
Samreboi			Wasa Mampong	Bonsa
Wasa Akropong				Bogoso
				Prestea
				Tarkwa 1*
				Tarkwa 2*

* City includes multiple clinics due to large population.

6 Hubs, 8-14 Clinics per Hub

Asankragua	Asempanaya	Axim	Daboase	Sefwi Wiawso	Tarkwa
Ankwawso	Adabokrom	Akropong	Agona Nkwata	Adukrom	Benso
Asankragua	Ahebenso	Axim	Akasakasa	Asawinso	Bogoso
Beposo	Asempanaya	Bonsa	Atieku	Asempanaye	Manso Amenfi
Enchi	Blacksmith	Bramienkor Jct.	Daboase	Bibiani	Prestea
Gyaaman	Essam	Elubo	Edumbanso	Bokaso	Tarkwa 1*
Krobo Abrokyire	Juabeso	Half Assini	Kojokrom	Bopa Nkwanta	Tarkwa 2*
Kwagyeikrom	New Debiso	Mpatapa	Kyekyewere	Dadieso	Wasa Akropong
Kwasikrom	Oseikojokrom	Nkroful	Mpohor	Domeabra	Wasa Nkran
Samreboi				Kodjour	
Wasa Mampong				Sefwi Wiawso	

* City includes multiple clinics due to large population